3477

ARS 42-180
APRIL 1971

DEVELOPMENT OF A MECHANICAL PICKUP HARVESTER FOR APPLES

Agricultural Research Service
UNITED STATES DEPARTMENT OF AGRICULTURE

Prepared by Harvesting and Farm Processing Research Branch, Agricultural Engineering Research Division, Agricultural Research Service, U.S. Department of Agriculture.

ACKNOWLEDGMENTS

The authors wish to thank the following individuals for their assistance:

Richard J. Wolthuis, Mechanical Engineering Technician, U.S. Department of Agriculture, for his help in construction and testing; David Friday, Grower and Manufacturer, Hartford, Mich., for his suggestions, comments, and assistance during testing; Herbert Teichman, owner of Skyline Orchards, Eau Claire, Mich., for his comments, suggestions, and cooperation during testing; Myron P. Kelsey, Associate Professor, Agricultural Economics, Michigan State University, East Lansing, for his help and construction of tables 6 and 7 and the calculations on page 10. Jerome Hull, Arthur Mitchell, and Donald Dewey, Professors, Horticultural Department, Michigan State University, East Lansing, Mich., for their comments, suggestions, and advice during the development of this project; John Harvey, Vice President of Research and Development, Harvey Harvester, Inc., Spring Lake, Mich., for assistance in the design and construction of component parts of the tested prototypes.

ABSTRACT

Mechanical harvesting of dropped apples for processing outlets may soon become standard practice as a result of the development of a new pickup harvester for apples in Michigan. Each year from 5 to 10 percent of the apple crop drops in the orchard during ripening and the subsequent harvest of the fruit. Occasionally unpredictable winds in particular areas cause an entire apple crop to drop. This paper discusses the development and economic implications of a new apple pickup harvester. With the prototype 1969 model, one worker harvested from 30 to 150 bushels of apples per hour, depending on fruit density and orchard conditions. After harvest, the apples were processed into juice in a commercial plant. At an estimated harvester cost of $3,500, about 2,500 bushels of dropped apples per season, worth $1.50 per hundredweight, must be harvested to break even.

DEVELOPMENT OF A MECHANICAL PICKUP HARVESTER FOR APPLES[1/]

B. R. Tennes,[2/] J. H. Levin,[2/] and R. T. Whittenberger[3/]

INTRODUCTION

According to the Michigan Crop Reporting Service, Michigan growers sold 555 million pounds of apples in 1968, and 680 million pounds in 1969. In an average year about 10 percent of the crop drops to the ground either during the natural ripening period or during hand harvesting. Thus, an average of approximately 62 million pounds of apples dropped onto orchard sod during 1968 and 1969. This is roughly equivalent to one-third of the total amount of apples needed annually for processing apple juice in Michigan. The remaining two-thirds is obtained mostly from off-grade fruit at processing plants.

The need for a mechanical apple pickup harvester has been increasing in recent years. In the first place, a shortage of competent labor exists now and will become greater in future years. When the crop is heavy, available labor is used almost exclusively to harvest prime-quality fruit. The 5 to 20 percent of the fruit that drops to the ground often is not picked up and is wasted. Consequently, a shortage of apples at juice plants sometimes occurs. Moreover, unpredictable winds sometimes cause the entire crop to drop from trees in a particular orchard or area. Again, labor for gathering up the dropped apples before decay sets in usually is not available. The entire crop may be lost. Finally, growers are not always able to meet the demands of workers for better pay, improved housing, and easier work.

OBJECTIVES

This study was initiated to: (1) Determine if an apple pickup harvester could be constructed that would harvest dropped fruit in a condition suitable for processing into apple juice or sauce; (2) learn about changes in horticultural practices that might be required for successful operation of the machine; and (3) determine conditions under which purchase of the machine by a grower or groups of growers would be economically feasible.

1/ Based on research conducted by the Agricultural Engineering Research Division and the Eastern Marketing and Nutrition Research Division, Agricultural Research Service, U.S. Department of Agriculture, in cooperation with the Agricultural Engineering Department, Michigan State University, East Lansing, Mich.

2/ Project engineer and leader, respectively, Fruit and Vegetable Harvesting Investigations Groups, Agricultural Engineering Research Division, ARS, USDA, at Agricultural Engineering Department, Michigan State University.

3/ Research biochemist, Eastern Marketing and Nutrition Research Division, ARS, USDA, at Philadelphia, Pa.

DESCRIPTION OF TEST HARVESTERS

The following three methods of picking up dropped apples were tested: (1) Spearing apples with spikes built onto a rotating drum, (2) wedging apples between rotating rubber disks arranged in a parallel series, and (3) sweeping apples up from the ground with a series of rubber fingers. In each case small-scale laboratory tests were carried out first, and the basic information obtained was then used to construct harvesters suitable for testing under field conditions.

Spiked-Drum Pickup Harvester

In 1966 a prototype model of a spiked-drum pickup harvester was constructed and tested (fig. 1).

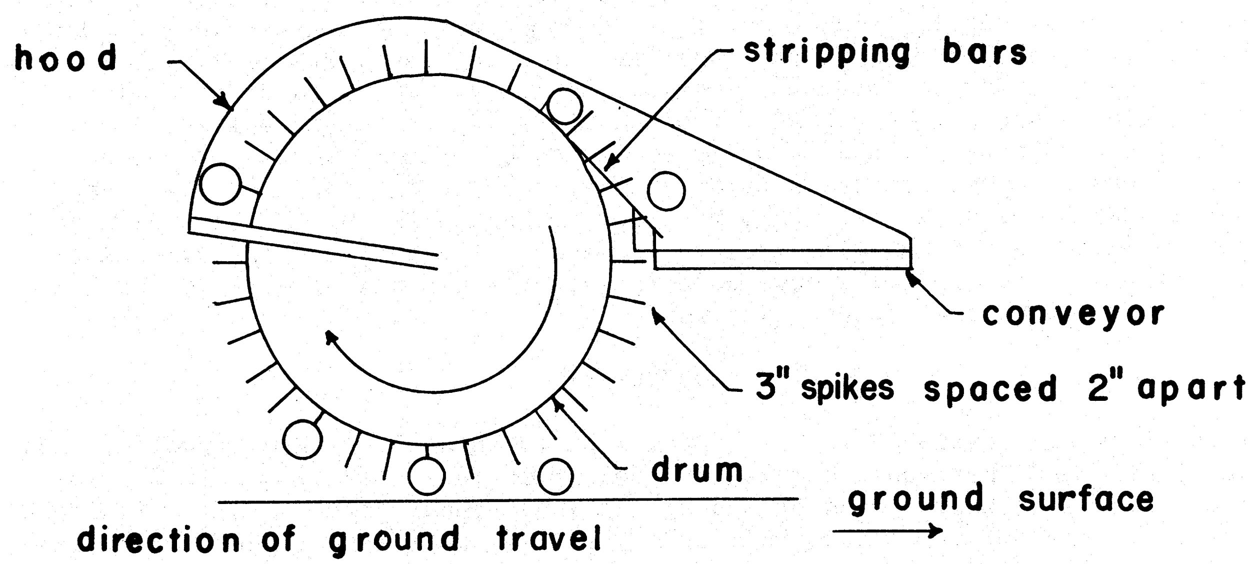

Figure 1. Side view diagram of spike-drum pickup harvester for apples.

Steel spikes 3 inches long and 5/32 inches in diameter were attached to an 18-gage steel drum 24 inches in diameter. The spikes were spaced 1.6 inches apart in rows 2 inches apart on the surface of the drum. The drum, driven from the rear tractor axle, was pivoted at its center to permit flotation on the ground surface. One gage wheel was located on each end of the drum. When the unit moved forward, the spikes penetrated dropped apples and lifted them from the ground as the drum rotated. The apples then were removed from the spikes by stripping bars located at the leading edge of the drum. After release, the apples rolled onto a conveyor from which they were deposited in a pallet box mounted on the unit.

Rubber Disk-drum Pickup Harvester

The first rubber disk-drum pickup harvester was constructed in 1967 (fig. 2).

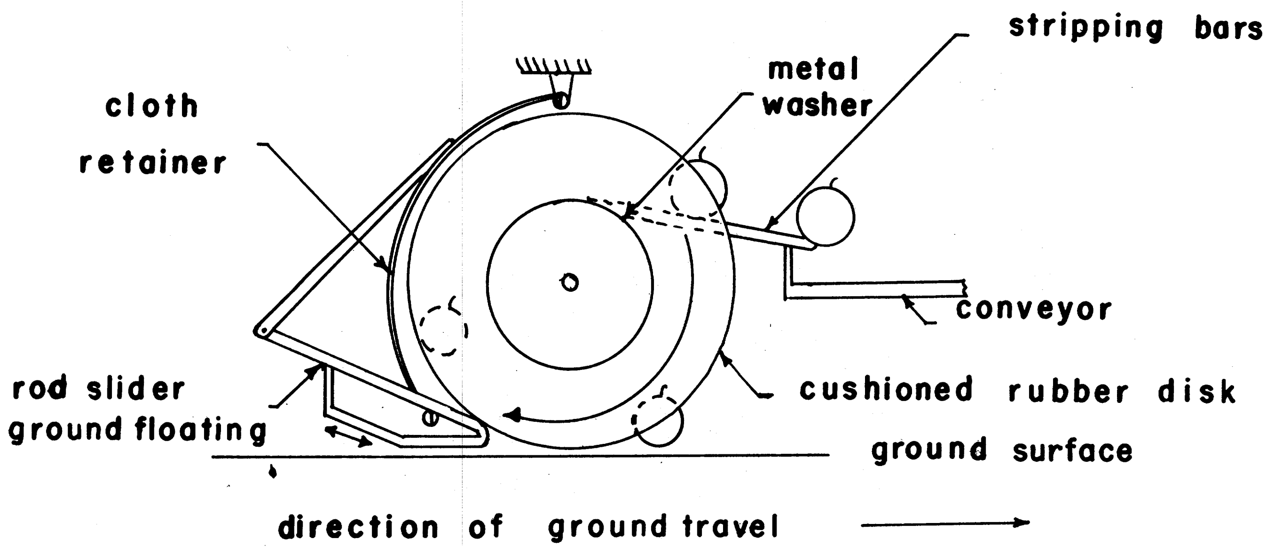

Figure 2. Side-view diagram of rubber disk-drum pickup harvester for apples.

The disks, 2 feet in diameter and made from natural rubber, were covered with polyurethane foam sheeting (2-pound density) having a vinyl skin. The disks, were assembled into a roller 3 feet long. The roller was powered hydraulically, and the disks rotated at about 1-1/2 times ground speed in the direction of travel. A bar (rod slider ground floating), located at ground level on the trailing side of the roller, helped to wedge apples between the pickup disks. A synthetic retaining cloth extended from the bar to the top of the roller assembly. The cloth helped to wedge and retain apples between disks as the disks rotated in an upward direction. The cloth was laced with a rubber cord that permitted the cloth to "give" with the flow of fruit on the disks.

A row of comb fingers located at the leading edge of the disk roller, extended between each disk. The fingers removed apples from between adjacent disks. The apples then rolled onto a conveyer, which deposited them in a pallet box mounted on the unit.

Rubber Finger Pickup Harvester

A prototype of this rubber finger pickup harvester was constructed and tested in 1969 (figs. 3 and 4). The rubber fingers (made originally for plucking turkeys) were hollow, 6 inches long, and about 7/8 inch in diameter. They were attached to a drum in rows 2-3/4 inches apart with the in-the-row fingers 2-1/2 inches apart. The drum rotated at about 1-1/2 times ground speed in the direction of travel. A retaining cloth was placed directly behind the drum to catch apples and direct their flow after their removal from the ground. The retaining cloth (fig. 3, A) is part of the drum assembly, both of which floated on the ground with the aid of x depth guide (gage) wheels located on each end of the drum.

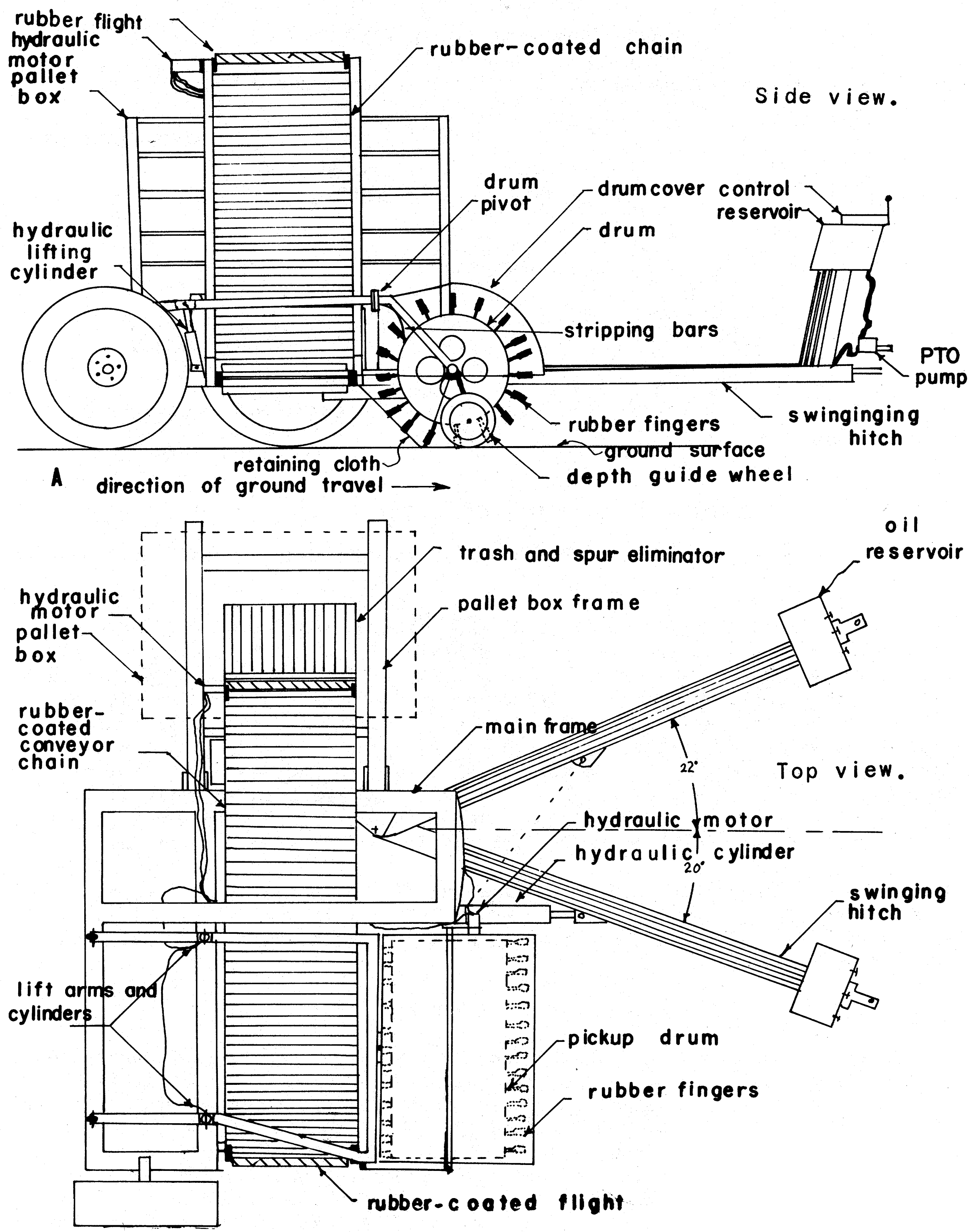

Figure 3. Diagram of a rubber finger pickup harvester for apples: A, Side view; B, top view.

Figure 4. A rubber finger pickup harvester for apples.

The drum was suspended at midpoint by a pivot pin from the main trailer. The lift arms of the drum extended back behind the conveyer (at rear of drum) to a point that was equal in height to the shaft of the drum when in operating position. Thus, the angle of separation between the retaining cloth and the apple conveyer was minimum.

As the harvester moved forward, dropped apples were swept from the ground onto the retaining cloth or gripped by the soft rubber fingers of the rotating drum. The fingers continued to sweep the apples up the retaining cloth until they spilled over onto the conveyer located at the rear of the drum. Any apples that became lodged between the fingers were removed by the stripping bars located near the top of the drum. From the conveyer, the apples passed across a trash and spur eliminator comprised of 10 rubber rollers with adjacent rollers turning in opposite directions (fig. 5). Finally, the apples dropped directly from the eliminator into a pallet box mounted on the unit.

The pickup and collecting mechanisms were mounted on a two-wheel trailer. The trailer had a swinging hitch (fig. 3, B) that was controlled from a control console located directly behind the tractor operator. Thus, the operator worked from the tractor seat in an open orchard row while the pickup assembly moved in beneath the tree canopy. The unit was driven from a hydraulic power takeoff (PTO) pump. Any tractor, therefore, in the 20- to 30-horsepower range could be used to operate the pickup unit.

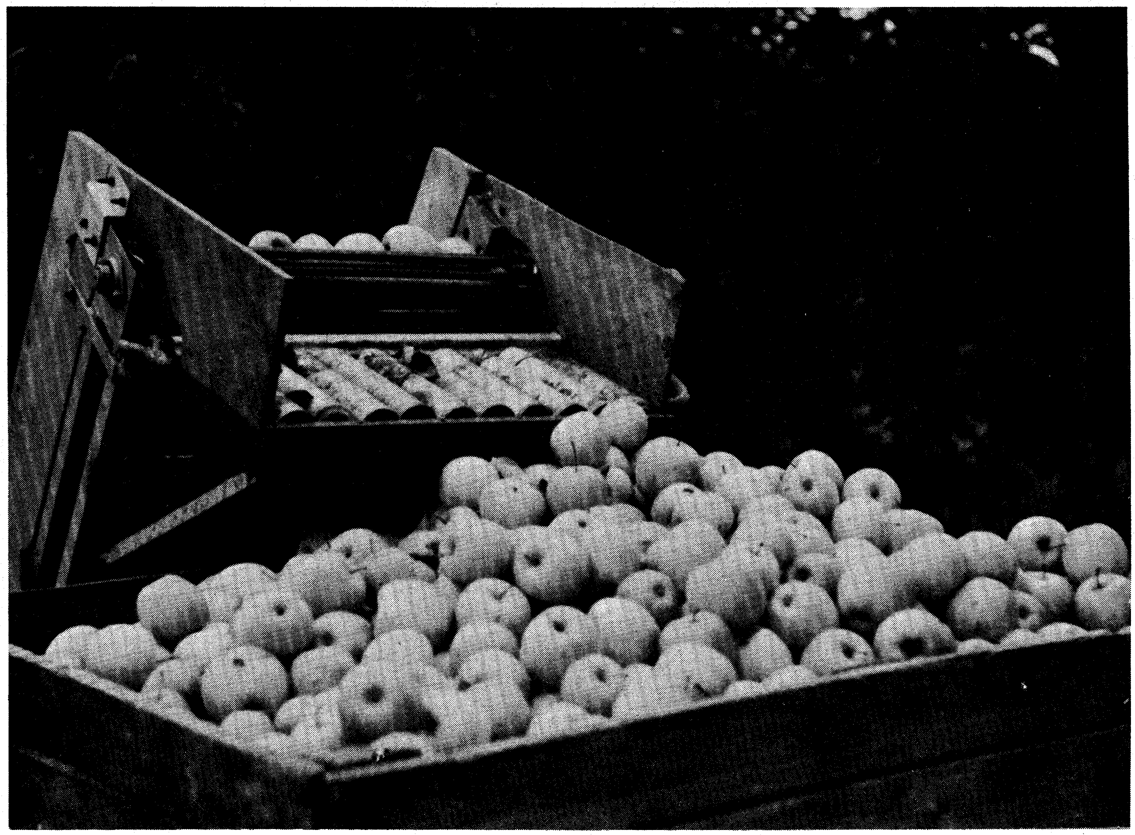

Figure 5. Closeup view of trash and spur eliminator and pallet box mounted on the rubber finger pickup harvester for apples.

PERFORMANCE OF TEST HARVESTERS

Each of the three pickup harvesters was tested under commercial conditions in several apple orchards. Relatively large volumes of dropped fruit were picked up. The recovered apples then were transported to juice plants or canneries where their processing characteristics were determined. Thus, information needed to develop a complete system of harvesting, handling, and processing was obtained.

Spiked-Drum Pickup Harvester

The spiked-drum pickup harvester picked up dropped apples at a rapid rate under dry, favorable conditions. For example, when fruit density (apple concentration on the ground) was high (15 bushels per tree), one worker picked up 150 bushels per hour with this harvester. When fruit density was low, one worker picked up only 30 to 40 bushels per hour. About 90 percent of the recovered apples had only one puncture mark.

Under wet conditions, however, the unit did not operate properly. The loose grass, weeds, and other trash on the ground were picked up by the spikes and subsequently jammed the machine.

No unusual difficulties were encountered in making sauce from the recovered apples in a commercial processing plant. However, processors feared that the penetration of a spike into apple flesh might in some cases contaminate the apple with foreign material. Since this objection was serious, work on the spiked-drum pickup harvester was discontinued.

Rubber Disk-Drum Pickup Harvester

Capacity of the rubber disk-drum pickup harvester was similar to that of the spiked-drum harvester. Difficulty was experienced, however, in maintaining proper functioning of the rubber disks and in obtaining sustained performance. In many cases the recovered apples were bruised excessively. For these reasons, work on this unit was discontinued in 1968.

Rubber Finger Pickup Harvester

Performance of the rubber finger pickup harvester in 1960 was far superior to that of the two previously tested harvesters. Efficiency was high, capacity was large, durability was good, bruise damage was low, and operating conditions were not critical. Approximately 1,000 bushels of apples, comprising five varieties in seven orchards, were picked up and processed into juice at two large commercial plants. Opinion was general that the unit was worthy of manufacture for commercial use.

Efficiency

The effect of fruit density on efficiency of recovery and rate of apple pickup is shown in table 1. Efficiency of recovery was high at both low and high fruit densities (99- and 97 percent recovery, respectively). However, considerably more bushels per hour were picked up when fruit density was high than when it was low.

Table 1. Effect of fruit density on efficiency of recovery and rate of apple pickup with rubber finger pickup harvester.

Fruit density in 1,000 square feet 1/ (bushels)	Recovery	Rate of pickup 2/
	Percent	Bushels per hour
1	99	21
30	97	88

1/ 1,000 square feet = area beneath average tree.
2/ Apples recovered by one person per hour.

Surprisingly, grass and weed height on the orchard floor had relatively little effect on efficiency of recovery (table 2). For example, recovery was 96

Table 2. Effects of ground cover and slope on apple recovery with rubber finger pickup harvester.

Orchard conditions	Recovery
	Percent
Grass and weeds, 2-4 inches high	99
Grass and weeds, 8-12 inches high	96
Slope 12°, machine travel 2.0 m.p.h.	40
Slope 12°, machine travel 0.2 m.p.h.	96

percent when the height was 8 to 12 inches. Harvester operation was impeded, however, by vines that became entangled around the drum. On level ground and on slight slopes (4°) the harvester performed well when traveling 2 miles per hour. On moderate slopes (approximately 12°) having a moderate fruit density, however, the speed of travel was reduced to 0.2 miles per hour to obtain satisfactory recovery.

Bruise Damage

Even though dropped apples can be used primarily for juice processing, bruise damage should be held to a practical minimum during pickup. Bruised apples spoil quickly, develop off-flavors, require immediate processing, and give low yields of final product.

Tests showed that the U.S. Department of Agriculture rubber finger pickup harvester did indeed treat apples gently (table 3). The sweeping and gripping action of the rubber fingers resulted in minimum bruise damage. Minor surface bruises that give no problem during processing occurred on 32 percent of the apples. The major part of the damage (5 percent of the apples by weight) occurred as apples dropped from the trash and spur eliminator into the pallet box. At this point major damage occurred on 3 percent of the apples. Necessary changes can be made to remedy this problem.

Table 3. Evaluation of bruise damage caused by rubber finger pickup harvester[1/]

Condition of apples	Apples picked up-- Before transfer to pallet box	After transfer to pallet box
	Percent	Percent
Major bruise damage (5 percent of fruit by weight)------------------------------------	0	3
Minor bruise damage or skin puncture---------	32	47
No bruise damage------------------------------	68	50

1/ Handpicked fruit had no bruise damage when placed on ground for tests.

In some cases it may be desirable to harvest apples by mechanically shaking them onto the ground and then recovering them with the rubber finger pickup harvester. Tests showed, however, that shaking large numbers of apples onto the ground all at once bruised apples extensively (table 4). Major bruise

Table 4. Comparative major bruise damage of apples shaken onto the ground and apples that dropped naturally from trees

Source of apples	Major bruise damage	Standard deviation
	Percent	Percent
Shaken onto ground---------	61	± 18
Natural drops--------------	15	± 4

damage occurred on 61 percent of these apples. In contrast, major bruise damage occurred on only 15 percent of the apples that dropped naturally from trees. These results indicate that apples shaken onto the ground should be collected and processed immediately.

Decay Problem

Apples that drop to the ground are subject to decay. The amount of decay depends largely on time, temperature, and extent of bruising. Dropped apples also may be damaged by rodents and other small animals. For these reasons the orchard floor must be prepared carefully if dropped apples are to be recovered and utilized. Decayed apples have no commercial value.

The extent of decay in dropped apples is shown in table 5. Apples freshly

Table 5. Extent of decay of apples on orchard ground

Origin of apples	Orchard	Decayed apples
		Percent
Freshly shaken onto ground	A	0
Natural drops, midseason	A	9
Natural drops plus mechanical harvesting spillage, end of season	B	30

shaken onto the ground contained no decay. Apples that had dropped naturally onto the ground during the first half of the harvest season contained 9 percent decay at midseason. In a different orchard at the end of the season natural drops plus apples spilled from a mechanical harvesting operation contained 30 percent decay. Recovery of these last apples was impractical.

The best procedures for eliminating decayed apples from an orchard floor have not yet been determined. Obviously, only a small percentage of decayed apples can be tolerated if the dropped apples are to be used for food. All decayed fruit must be removed before the rest of the fruit is processed. Perhaps a rot-free bed could be prepared first by mechanically picking up and discarding the original set of drops. Subsequent passes with the pickup harvester would recover rot-free fruit. Good judgment must be used in deciding what should be done in each orchard.

ECONOMICS OF A RUBBER FINGER PICKUP HARVESTER

Cost calculations for operating a rubber finger pickup harvester are shown in table 6. A cost of $0.31 per hundredweight of recovered apples, or $9.39 per hour of operation, was obtained.

The annual overhead cost of a rubber finger pickup harvester, with an initial value of $3,500, depreciated over a 5-year period, was $972.50. Calculations for this are as follows:

Depreciation ($500 salvage - 5 years straight line)	$600.00
Interest (8 percent on average value of $2,250)	180.00
Repair and maintenance (4 percent of new cost)	140.00
Taxes, insurance, and storage (1.5 percent of new cost)	52.50
Annual overhead cost	972.50
Box rental of 30 boxes at $2.00 each	60.00
Auxiliary equipment overhead---$58.00 per 1,000 bushel	

Table 6. Operating cost for a rubber finger pickup harvester based on recovery of 9,000 pounds of apples every 3 hours

Item	Cost	
2-Plow tractor	$0.68 per hr. x 3 hr. =	$ 2.04
Tractor driver	2.24 per hr. x 3 hr. =	6.72
Forklift and tractor	0.92 per hr. x 3 hr. =	2.76
Forklift driver	2.24 per hr. x 3 hr. =	6.72
Truck mileage	0.08 per mile for 40 miles =	3.20
Truck driver	2.24 per hr. x 3 hr. =	6.72
Total cost, 3 hr.	=	28.16
Cost per hundredweight	=	0.31
Cost per hour	=	9.39

Growers wish to know the conditions under which buying a rubber finger pickup harvester would be economically feasible. Data in table 7 indicate that if dropped apples were worth $1.50 per hundredweight, a grower would need to harvest 3,000 bushels per year in order to make a reasonable profit--$0.20 to $0.40 per hundredweight. If he harvested only 2,500 bushels, he probably would break even.

Approximately 800 Michigan growers have 50 or more acres of apple orchards. Each of these growers loses probably 3,000 to 4,000 bushels of dropped apples per year. Thus, a potential need for several hundred pickup harvesters exists in Michigan alone. Nationally, a need for several thousand harvesters exists. In addition, small growers having less than 3,000 bushels of dropped apples per year may wish to own a machine jointly or to participate in custom harvesting.

Between 10 and 20 commercial rubber finger pickup harvesters were manufactured for trials in 1970. Growers should observe the performance of the commercial unit. Results reported in this paper apply only to the USDA prototype model. In the long run we are confident that this pickup harvester will find a useful place in the apple industry.

Table 7. Relation between amount of apples harvested and total operating cost for a rubber finger pickup harvester 1/

Apples harvested		Time to harvest (65 bu./hr.)	Box rental and harvester overhead	Cost		
Bushels	Hundredweight			Per bushel	Per hundredweight	Total
		Hours	Bushel			
1,000	450	15	$1.03	$1.23	$2.73	$1,227.40
2,000	900	30	.51	.71	1.58	1,426.80
3,000	1,350	45	.34	.54	1.20	1,626.20
4,000	1,800	60	.26	.46	1.02	1,825.60
5,000	2,250	75	.21	.42	.93	2,025.00
6,000	2,700	90	.17	.37	.82	2,224.40
7,000	3,150	105	.15	.36	.78	2,423.80
8,000	3,600	120	.13	.33	.73	2,623.20
9,000	4,050	136	.11	.31	.69	2,822.60
10,000	4,500	150	.10	.30	.67	3,022.00

1/ Assuming 1 bushel = 45 pounds.

CONCLUSIONS

With the U.S. Department of Agriculture rubber finger pickup harvester, one worker harvested from 30 to 150 bushels of apples per hour, depending on fruit density and orchard condition.

The harvester performed well in orchards where the ground cover was mowed and the trash was removed. The unit was durable and caused only minor bruise damage.

No changes in conventional processing techniques were required to process high-quality juice from the harvested apples.

A grower probably would need to harvest about 3,000 bushels of dropped apples per year to make the pickup operation economically feasible. This calculation is based on a cost of $3,500 for the pickup harvester and a value of $1.50 per hundredweight for recovered apples.